

AN LDRD SUCCESS STORY

National Nuclear Security Administration's



**Lawrence Livermore
National Laboratory**



Hydrocarbon sludge and dissolved contaminants in a two-story-tall Visalia separator tank.

SOLVING RESTORATION NIGHTMARES

Laboratory Directed Research and Development (LDRD) investments helped solve a nearly impossible environmental restoration problem at a utility-pole treatment yard in Southern California, one of the original Environmental Protection Agency Superfund sites.

POLLUTED POLE YARD

For 80 years, Southern California Edison had used the four-acre Visalia facility to dip utility poles in creosote and PCP (pentachlorophenol) wood-preservative compounds, which can have devastating effects on humans and wildlife. By the 1970s, these highly toxic substances had seeped into the soil approximately 100 feet, resulting in Visalia being designated a significant risk to public health.

Environmental restoration of the site was considered to be essentially impossible. Estimates suggested an almost-permanent pump-and-treat operation would be required just to prevent migration of contaminated underground water, at a cost of greater than \$100 million. For nearly 20 years, Southern California Edison removed contaminants at the lethargic rate of 10 pounds per week using a standard cleanup method known as pump-and-treat. Water is pumped from beneath the water table, treated to remove or destroy contaminants, and returned underground. Huge amounts of water must be flushed through the contaminated area, and even then the contamination may not be completely removed. More than a million pounds of hydrocarbon contaminants still remained.

In the summer of 1997, Environmental Services of Bakersfield—the first commercial site licensee of the Laboratory's dynamic underground stripping technology—along with Southern California Edison and Livermore geophysicists, employed LDRD-developed technologies to monitor and remove contaminants 5,000 times faster than with the pump-and-treat process. The entire site was cleaned in 10 years with a corresponding tenfold cost savings, and removed from the Superfund listing in September 2009.

SUPERFUND SITE RESTORED 100 YEARS AHEAD OF SCHEDULE

THERMAL REMEDIATION

The Environmental Protection Agency named hundreds of sites to the Superfund list. Thousands of additional properties are also polluted with underground accumulations of solvent and hydrocarbon contaminants—the most serious causes of groundwater pollution.

Livermore's dynamic underground stripping and hydrous pyrolysis oxidation technologies yielded a contaminant removal rate of about 46,000 pounds per week at Visalia. These technologies were the result of several unrelated LDRD projects undertaken only a few years earlier and first demonstrated in the cleanup of an underground gasoline spill at the Livermore site in 1993. The thermal remediation process employed at Visalia has led the agency to rethink the assumption that complete contaminated groundwater cleanup is not possible.

- Both thermal technologies had their origins in a 1991 project in which investigators studied oil and gas deposits to enable enhanced discovery and recovery. Through experiments and modeling, the team also researched the fundamental behavior of liquid contaminants and interactions with their geologic surroundings to evaluate site response to various recovery techniques, including use of steam.
- Also in 1991, "Using Electrical Resistance Tomography to Monitor Subsurface Water Movement" provided Visalia with near-real-time images of underground processes between monitoring wells. Because soil electrical properties vary with temperature, soil type, and fluid saturation, baseline measurements with electrical resistance tomography can predict steam pathways and monitor progress of subsurface heating.
- Chemical analysis was facilitated by a series of LDRD projects that demanded accurate real-time chemical analysis in the field. A multiplatform computer code was produced that included such site-dependent effects as water and soil chemistry, nutrients, temperature, and microbial activity.
- In 1997 a system of thermal technologies was fully developed to rapidly remove sources of contaminant plumes and concurrently prevent their further dispersal. To prevent displacement of contaminated groundwater and take advantage of accelerated transport caused by steam injection, researchers proposed a reactive, permeable barrier downstream of steam injection wells.

ABOUT LDRD

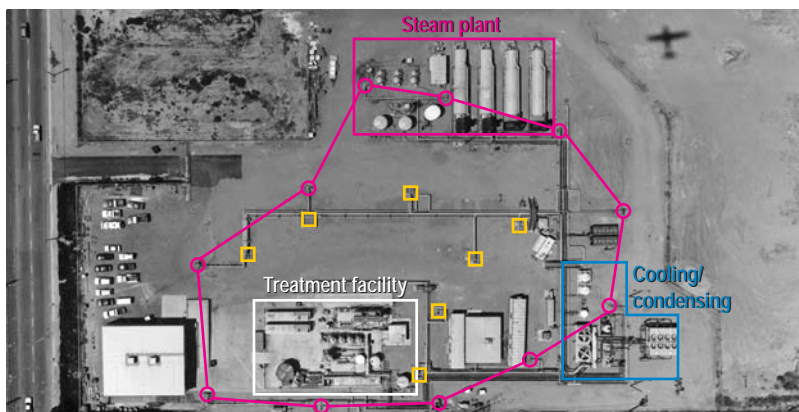
The Laboratory Directed Research and Development (LDRD) Program is Lawrence Livermore National Laboratory's primary mechanism for funding cutting-edge R&D to enhance the Laboratory's scientific vitality. Established by Congress in 1984, LDRD collects funds from sponsored research and competitively awards those funds to high-risk, potentially high-payoff projects aligned with Laboratory missions.



For years, Livermore scientists have been looking for better ways to clean up soil and groundwater contamination, in part because both the Livermore Laboratory and its remote test site were also part of the Superfund list as a result of U.S. Navy, Atomic Energy Commission, and DOE operations. The Visalia pole yard shown above was the first full-scale implementation of thermal remediation technologies developed with support from the LDRD Program.

DYNAMIC UNDERGROUND STRIPPING

In dynamic underground stripping, the area to be cleaned is ringed with wells for injecting steam. Extraction wells in the central area are used to vacuum out vaporized contaminants. To ensure that thick layers of less permeable soils are heated sufficiently, electrode assemblies are sunk into the ground and the ground is heated, which forces trapped liquids to vaporize and move to the steam zone for removal by vacuum extraction. These combined processes achieve a hot, dry, contaminant-free zone of earth surrounded by cool, damp, untreated areas. Steam injection and heating cycles are repeated as long as underground imaging shows that cool regions remain.



In this aerial view of the Visalia site, steam injection wells for dynamic underground stripping are shown as magenta circles. The mobilized contaminants are extracted from wells shown in yellow.

HYDROUS PYROLYSIS OXIDATION

About half the cost of a cleanup using dynamic underground stripping is in treating the recovered groundwater and disposing of contaminated material. Hydrous pyrolysis oxidation is a process that converts contaminants in the ground to benign products such as carbon dioxide, chloride ions, and water. Contaminants are destroyed in place by injecting oxygen, steam, and air to build a heated, oxygenated zone in the subsurface. When injection is halted, the steam condenses and contaminated groundwater returns to the heated zone. The groundwater then mixes with the condensed steam and oxygen, which destroys dissolved contaminants. This process avoids many of the problems encountered in other underground oxidation schemes.



The large dark boilers in the background, originally developed to provide steam for enhanced oil recovery in nearby oil fields, provided the steam power to vaporize underground contaminants. Livermore researchers in the foreground adjust the flow of injected noble-gas tracers used to monitor and control the remediation process.